87-4228

Streamflow Statistics for Streams on the Puyallup Indian Reservation, Washington

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 87-4228

Prepared in cooperation with the
PUYALLUP TRIBE OF INDIANS

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STREAMFLOW STATISTICS FOR STREAMS ON THE PUYALLUP INDIAN RESERVATION, WASHINGTON

by David L. Kresch and Edmund A. Prych

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Water-Resources Investigations Report 87-4228

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Tacoma, Washington
1989

DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

For the convenience of readers who may prefer to use metric units rather than the inch-pound units used in this report, values may be converted by using the following factors:

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	25.4	millimeter (mm)
	2.540	centimeter (cm)
	0.0254	meter (m)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	28.32	liter per second (L/s)

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Sea Level Datum of 1929."

degrees Fahrenheit ($^{\circ}F$) to degrees Celsius ($^{\circ}C$): $^{\circ}C = 5/9\ (^{\circ}F-32)$

STREAMFLOW STATISTICS FOR STREAMS ON THE PUYALLUP INDIAN RESERVATION, WASHINGTON

By David L. Kresch and Edmund A. Prych

ABSTRACT

Streamflow statistics consisting of low-flow frequency values, high-flow frequency values, mean monthly flows, mean annual flow, flow-duration values, and peak-flow frequency values were estimated for each of 16 sites on small streams within the Puyallup Indian Reservation, Washington. Contributing surface-drainage areas above these sites range from 0.62 to 16.7 square miles. Streamflow statistics were also computed for the stream-gaging station Puyallup River at Puyallup (drainage area 948 square miles) from records for water years 1943 through 1982. The Puyallup River enters the reservation 0.8 mile upstream of the gage.

Station regression equations were used to transfer all streamflow statistics except for peak flows from long-term gaging stations to the small-stream sites. An equation for each small-stream site was developed by regressing approximately 12 monthly measurements of discharge at that small-stream site with respect to concurrent daily mean discharges at a long-term gaging station. The coefficients of correlation between the discharges used to determine the equations range from 0.98 to 0.79 except for one value of 0.58.

Peak discharges for the small-stream sites were estimated by regional regression equations. These equations express peak discharge as a function of surface-drainage area and mean annual precipitation, and were developed with data from 26 gaging stations in the Puget Sound area.

INTRODUCTION

Salmon and steelhead trout have traditionally played a major role in the economy and culture of the Puyallup Indian Tribe. The flows in the streams of the Puyallup Indian Reservation are of vital interest to the tribe because many of these streams either serve as spawning areas or provide migration routes to spawning areas for these fish species.

In 1981, the U.S. Geological Survey, in cooperation with the Puyallup Tribe of Indians, began a study of the water resources of the lower Puyallup River valley and adjacent uplands. The results of this investigation are being released as a series of three reports describing the quality of surface and ground waters, streamflow statistics, and the availability of ground water. This report presents streamflow statistics for the Puyallup Indian Reservation.

Purpose and Scope

The purpose of this report is to present streamflow statistics estimated for seven small streams and their tributaries on the Puyallup Indian Reservation and statistics computed for stream-gaging station 12101500 on the Puyallup River at the reservation. The statistics presented are as follows.

1. Lowest mean daily discharges for periods of 1, 3, 7, 14, and 30 consecutive days with average recurrence intervals of 2 and 10 years. All of these statistics were computed for the gaging station on the Puyallup River. Only the 7-, 14-, and 30-day low-flow statistics were estimated for the small streams because 1- and 3-day low-flow statistics for small streams can be sensitive to minor diversions and blockages.
2. Highest mean daily discharges for periods of 1, 3, 7, 15, and 30 consecutive days with average recurrence intervals of 2 and 10 years.
3. Mean monthly and annual discharges.
4. Daily mean discharges equaled or exceeded 10, 25, 50, 75, and 90 percent of the time. These discharges are also referred to as flow-duration values elsewhere in this report.
5. Annual peak discharges with average recurrence intervals of 10, 50, and 100 years.

Streamflow statistics for the Puyallup River were computed from discharge records for stream-gaging station 12101500 (Puyallup River at Puyallup, Washington), located at river mile 6.6. Streamflow statistics were estimated for 16 sites on seven small streams and their tributaries--Clarks, Clear, Diru, Hylebos, Swan, and Wapato Creeks and Fife Ditch--near where they enter the Puyallup Indian Reservation and near their mouths (see table 1). The locations of these sites are shown on plate 1.

Station regression or regional regression techniques were used to estimate most discharges for the small reservation streams. The station regression analyses were based on discharge measurements made approximately once a month for a year at each of the small-stream sites and discharge records for seven long-term gaging stations. The regional regression analyses were based on peak-discharge records for 26 long-term gaging stations in the Puget Sound area. At the two sites on Swan Creek, peak discharges were computed from

records of the peak-stage partial-record gaging station Swan Creek near Tacoma (12102200).

Table 1.--Small-stream sites on or near the Puyallup Indian Reservation for which streamflow statistics were estimated

Station number	Small-stream site	Drainage area (square miles)
12101478	Wapato Creek diversion to Puyallup River at North Puyallup	1.48
12102020	Diru Creek at inflow to hatchery near Puyallup	1.17
12102050	Clarks Creek tributary at Pioneer Way near Puyallup	1.56
12102075	Clarks Creek at Tacoma Road at Reservation Boundary	13.0
12102100	Clarks Creek at River Road near Puyallup	16.3
12102110	W.F. Clear Creek at 72nd St. E., Tacoma	.74
12102115	E.F. Clear Creek at 72nd St. E., Tacoma	1.52
12102175	Clear Creek at 31st Ave. Ct. E., Tacoma	8.53
12102202	Swan Creek at Flume Line Road, Tacoma	2.28
12102212	Swan Creek at Pioneer Way, Tacoma	3.07
12102490	Wapato Creek at Union Pacific RR near North Puyallup	.62
12102510	Wapato Creek at 12th St. E., Fife	3.47
12102900	Hylebos Creek above tributary at 5th Ave., Milton	4.77
12103000	West tributary to Hylebos Creek near Milton	7.33
12103025	Hylebos Creek at 8th Ave. E., Fife	16.7
12103035	Fife Ditch at 54th St. E., Fife	2.03

All gaging-station streamflow data and basin characteristics used in the regression analyses were retrieved from the National Water Data Storage and Retrieval (WATSTORE) system, and all gaging-station streamflow statistics computed from the streamflow data were obtained using standard WATSTORE statistical computer programs (Hutchinson, 1975, chapter IV, sections F and G; Lepkin and others, 1979, chapter I, section A-C and chapter II, section B). Computer programs developed by Statistical Analysis System (SAS) Institute, Incorporated,[1] were used for all station and regional regression analyses (SAS Institute, Inc., 1979, part 3, pages 173-178, 237-264, 317-330, and 391-396).

[1]Use of firm name in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Location and Extent of the Study Area

The study area is the Puyallup Indian Reservation, as established by the Medicine Creek Treaty of 1854 (pl. 1). The reservation is located in the lower Puyallup River valley, in the southeastern part of the Puget Sound lowland of western Washington State. The streams investigated are all within the Puyallup River drainage basin except for Hylebos and Wapato Creeks, which drain directly into Puget Sound at Commencement Bay. The section of the Puyallup River inside the Puyallup Indian Reservation extends from 0.8 mile upstream to 5.1 miles downstream of the gage at Puyallup. The drainage area of the Puyallup River basin above the gage is 948 square miles. The contributing surface-drainage areas (more simply referred to as drainage areas elsewhere in this report) above the small-stream sites for which streamflow statistics were estimated range from 0.62 to 16.7 square miles.

Topography and Geology

The topography of the Puyallup Indian Reservation ranges from the flat flood plain of the lower Puyallup River to steep hillslopes that border the valley and ascend to the adjacent uplands. The topography of the uplands is characterized as a series of gently rolling hills. The flood plain is generally less than 50 feet above sea level and the adjacent uplands reach maximum altitudes of about 500 feet. The drainage basins of the reservation streams, all of which extend beyond the reservation boundaries, reach maximum altitudes of about 600 feet (pl. 1).

The floor of the Puyallup River valley is composed of alluvium of the Quaternary age that is underlain by marine sediments and glacial drift (Walters and Kimmel, 1968). The alluvium is mostly silt, sand, and clay, but contains some gravel. The uplands adjacent to the valley are glacial-drift plains formed during glacial periods of the Pleistocene Epoch.

Land Use

Land use varies widely in the study area. On the Puyallup River valley floor near Commencement Bay (Tacoma tideflats), land use is primarily industrial. Commercial developments are also located in this area, as well as in the cities of Fife, Milton, and Puyallup. Single-family residences and apartments are scattered throughout the valley floor and on the adjacent uplands. Much of the land on the valley floor south of Interstate Highway 5 is used for agriculture. The steep sides of the Puyallup River valley, the canyons through which many of the small streams flow, and scattered locations in the uplands are forested.

Climate

The climate of the area is moderate because of the proximity of Puget Sound and the Pacific Ocean. Winter temperatures usually remain above freezing, and summer temperatures are seldom above 80 ^{o}F. Most precipitation occurs as rainfall, and the mean annual precipitation within the study area is about 38 inches. Approximately 75 percent of the precipitation occurs from October through March (U.S. Department of Commerce, 1981).

STREAMFLOW STATISTICS

Streamflow statistics for the Puyallup River (table 2) were computed from discharge records for the gaging station on the Puyallup River at Puyallup for the period 1943 through 1982. Although the period of record for this station began in 1914, the record prior to 1943 does not reflect the present flow conditions because discharges on the White River, a major tributary to the Puyallup River, have been regulated since 1943 by Mud Mountain Reservoir, a flood-control facility. Discharge in the Puyallup River at Puyallup is also affected by two hydropower installations, one on the Puyallup River near Electron, with limited storage capacity, and the other on the White River at Lake Tapps. Both of these installations began operation prior to 1914.

Table 2.--Streamflow statistics for Puyallup River at gaging station 12101500 (Puyallup River at Puyallup, Washington)

Streamflow statistic	Discharge, in cubic feet per second[a]	Streamflow statistic	Discharge, in cubic feet per second[a]
1-day 2-year low flow	780	October mean flow	2,000
1-day 10-year low flow	550	November mean flow	3,420
3-day 2-year low flow	930	December mean flow	4,720
3-day 10-year low flow	700	January mean flow	4,520
7-day 2-year low flow	1,140	February mean flow	4,200
7-day 10-year low flow	840	March mean flow	3,230
14-day 2-year low flow	1,240	April mean flow	3,370
14-day 10-year low flow	930	May mean flow	4,130
30-day 2-year low flow	1,420	June mean flow	4,780
30-day 10-year low flow	1,040	July mean flow	3,280
		August mean flow	2,120
		September mean flow	1,770
1-day 2-year high flow	17,600	Annual mean flow	3,460
1-day 10-year high flow	29,500		
3-day 2-year high flow	14,400	Flow exceeded:	
3-day 10-year high flow	24,100	10 percent of the time	5,890
7-day 2-year high flow	11,400	25 percent of the time	4,180
7-day 10-year high flow	18,200	50 percent of the time	2,950
15-day 2-year high flow	8,900	75 percent of the time	2,020
15-day 10-year high flow	12,900	90 percent of the time	1,430
30-day 2-year high flow	7,200		
30-day 10-year high flow	9,700	10-year peak flow	[b]35,200
		50-year peak flow	[b]46,800
		100-year peak flow	[b]50,000

[a]Computed, unless otherwise indicated, on the basis of gaging station 12101500 discharge records for water years 1943 through 1982. Flows during this period affected by regulation at Mud Mountain Dam, a flood-control dam, and Lake Tapps, a reservoir for hydroelectric power operation, both on the White River, a major tributary to the Puyallup River, and at a hydroelectric facility on the Puyallup River near Electron.

[b]Obtained by written communication (1985) from Richard W. McLaughlin, Chief, Hydrology and Hydraulics Branch, U.S. Army Corps of Engineers (COE) Seattle, Wash. Discharges were determined by COE taking into consideration their guidelines for operation of Mud Mountain Dam.

Because of the paucity of discharge records for the small streams on the reservation (table 3), most flow statistics for these streams were determined by statistical methods using data from gaging stations on other streams in the Puget Sound area. All streamflow statistics except for peak discharges were estimated for the small-stream sites using station regression equations that were derived by regressing discharge measurements made at the small-stream sites with respect to daily mean discharges at selected long-term gaging stations. Peak discharges were estimated for most small-stream sites using regional regression equations that were developed using drainage area and mean annual precipitation as independent parameters.

Streamflow statistics estimated using the station regression equations were generally within the range of discharges measured at the sites, except for some of the high-flow statistics, which were typically 25 to 75 percent greater than the highest measured discharges. However, peak discharges estimated for the sites using these equations were typically at least three times as great as the maximum discharges measured. The use of the station regression equations to estimate peak discharges at the small-stream sites would require extending the equations well beyond the range of discharges used in their development. Therefore, regional regression equations were developed and used to estimate peak discharges for the sites.

Ninety-five-percent confidence bands were computed for all streamflow statistics estimated for the small-stream sites. The upper and lower limits of these bands are defined as being two standard errors of prediction above and below the estimated discharges, respectively. There is a 95-percent probability that the true values of the estimated discharges lie within these bands.

Table 3.--Periods of record for gaging stations on small streams that flow through the Puyallup Indian Reservation

Station number	Station name	Period of record (calendar years)	Drainage area (square miles)	Type of record
12102000	Clarks Creek at Puyallup	1946-48	1.88	daily mean discharge
12102200	Swan Creek near Tacoma	1951-71	2.15	annual peak discharge
12102500	Wapato Creek near Tacoma	1949	6.46	daily mean discharge
12102800	S.F. Hylebos Creek near Puyallup	1948-66	.27	annual peak discharge
12103000	West tributary to Hylebos Creek near Milton	1949-50	7.33	daily mean discharge

Peak discharges for Swan Creek at the reservation boundary were obtained from a flood-frequency analysis of the 21 annual peak discharges at crest-stage gage 12102200 (Swan Creek near Tacoma), which was located 0.2 mile upstream of the reservation boundary. The peak discharges determined for the Swan Creek gage were also used as the best estimates of the peak flows at the site on Swan Creek near its mouth, because peak discharges estimated by regional regression for that site were less than those determined for the gage.

Peak-discharge data for crest-stage gage 12102800, which was located on S.F. Hylebos Creek and had a drainage area of only 0.27 square mile, could not be used in the determination of peak discharges for either of the two sites on Hylebos Creek, which have drainage areas of 4.77 and 16.7 square miles, because the gage was located too far upstream from them. Historic daily mean discharges for gaging stations 12102000, 12102500, and 12103000 that were operated on Clarks Creek, Wapato Creek, and Hylebos Creek tributary, respectively, were not used in the determination of streamflow statistics for those streams because the periods of record for the gages, which range from 1 to 3 years, were all considered to be too short.

Selection of Gaging Stations

Twenty-six gaging stations, which were selected from all the gages located in the Puget Sound area, were used to develop station and regional regression equations for the small-stream sites (see table 4 and figure 1). These gaging stations were selected on the basis of (1) amount and type of precipitation, (2) mean basin altitude, (3) size of drainage area, (4) amount of runoff per unit drainage area, (5) amount of streamflow diversion, and (6) length of record. Stations that were not selected did not meet the criteria for one or more of these basin characteristics.

Precipitation data were used to establish a western geographical boundary for the selection of gaging-station records. Streams that drain the Olympic Mountains in northwestern Washington generally receive two to three times as much precipitation as do the Puyallup Indian Reservation streams, therefore, gaging-station data for streams west of Hood Canal were not used.

Selection of gaging stations on streams that drain the western slopes of the Cascade Range in central Washington was based on the mean altitude and annual snowfall in the drainage basins. Data for gaging stations located in drainage basins with mean altitudes greater than 2,000 feet or more than 30 inches of snow annually were generally not used, because they were not representative of the study area, which receives nearly all its precipitation as rain.

Gaging stations with drainage areas greater than 70 square miles were not used because streamflow statistics estimated for them probably would not be similar to those for the small reservation stream sites, which have drainage areas that range from 0.62 to 16.7 square miles.

This elimination process left records from 50 gaging stations for potential use in developing the station and regional regression equations. Streamflow statistics for these records were plotted against the respective drainage areas. Those gages at which the streamflow per unit drainage area is considerably different than at the majority of the other gages were not included in the regression analyses.

Table 4.--Gaging-station records used in regression analyses

Station number	Station name	Period of record through 1980[a] (calendar years)	Drainage area (square miles)	Mean annual precipitation (inches)
12063000	Union River near Bremerton	1945-59[b]	3.16	57
12064500	Mission Creek near Bremerton	1945-53	1.83	62
12065500	Gold Creek near Bremerton	1945-70	1.51	61
12067000	Panther Creek near Bremerton	1945-53	.98	62
12068500	Dewatto Creek near Dewatto	1947-54, 1958-74	18.4	61
12069550	Big Beef Creek near Seabeck	1969-81	13.8	55
12070000	Dogfish Creek near Poulsbo	1947-71	5.01	37
[c]12073500	Huge Creek near Wauna	1947-69, 1977-80	6.47	54
[c]12108500	Newaukum Creek near Black Diamond	1944-50, 1952-80	27.4	48
[c]12112600	Big Soos Creek near Auburn	1960-80[d]	66.7	47
12118500	Rock Creek near Maple Valley	1945-73[e]	12.6	53
[c]12120000	Mercer Creek near Bellevue	1945, 1955-80	12.0	43
[c]12120500	Juanita Creek near Kirkland	1945, 1963-80	6.43	40
12121000	Issaquah Creek near Issaquah	1945-64	27.0	66
[c]12121600	Issaquah Creek near mouth	1963-80	54.7	53
12121700	Tibbets Creek near Issaquah	1963-68, 1971-76	3.90	55
12123000	Cottage Lake Creek near Redmond	1945, 1955-65	10.7	43
12124000	Evans Creek near Redmond	1955-76	13.0	45
12126000	North Creek near Bothell	1945-72	24.6	38
[c]12127100	Swamp Creek at Kenmore	1963-80	23.1	39
12127600	McAleer Creek at Lake Forest Park	1963-72	7.80	38
12141000	Woods Creek near Monroe	1946-71	56.4	48
12146000	Patterson Creek near Fall City	1947-50, 1955-71	15.5	47
12147000	Griffin Creek near Carnation	1945-70	17.1	53
12153000	Little Pilchuck River near Lake Stevens	1946-51, 1952-70	17.0	42
12157000	Quilceda Creek near Marysville	1946-69	15.4	37

[a] Streamflow statistics for station records used in regional regression analyses were computed in 1982 using records through 1980, the most current year of record available at that time.

[b] Used record through 1955 calendar year only because of streamflow regulation since 1956.

[c] Station used in station regression analyses because it was active during June 1983 through May 1984, which is when discharge measurements were made at small-stream sites (see fig. 1).

[d] Used record since 1966 calendar year only because of significant diversions prior to then.

[e] Used record through 1962 calendar year only because of significant diversions since 1963.

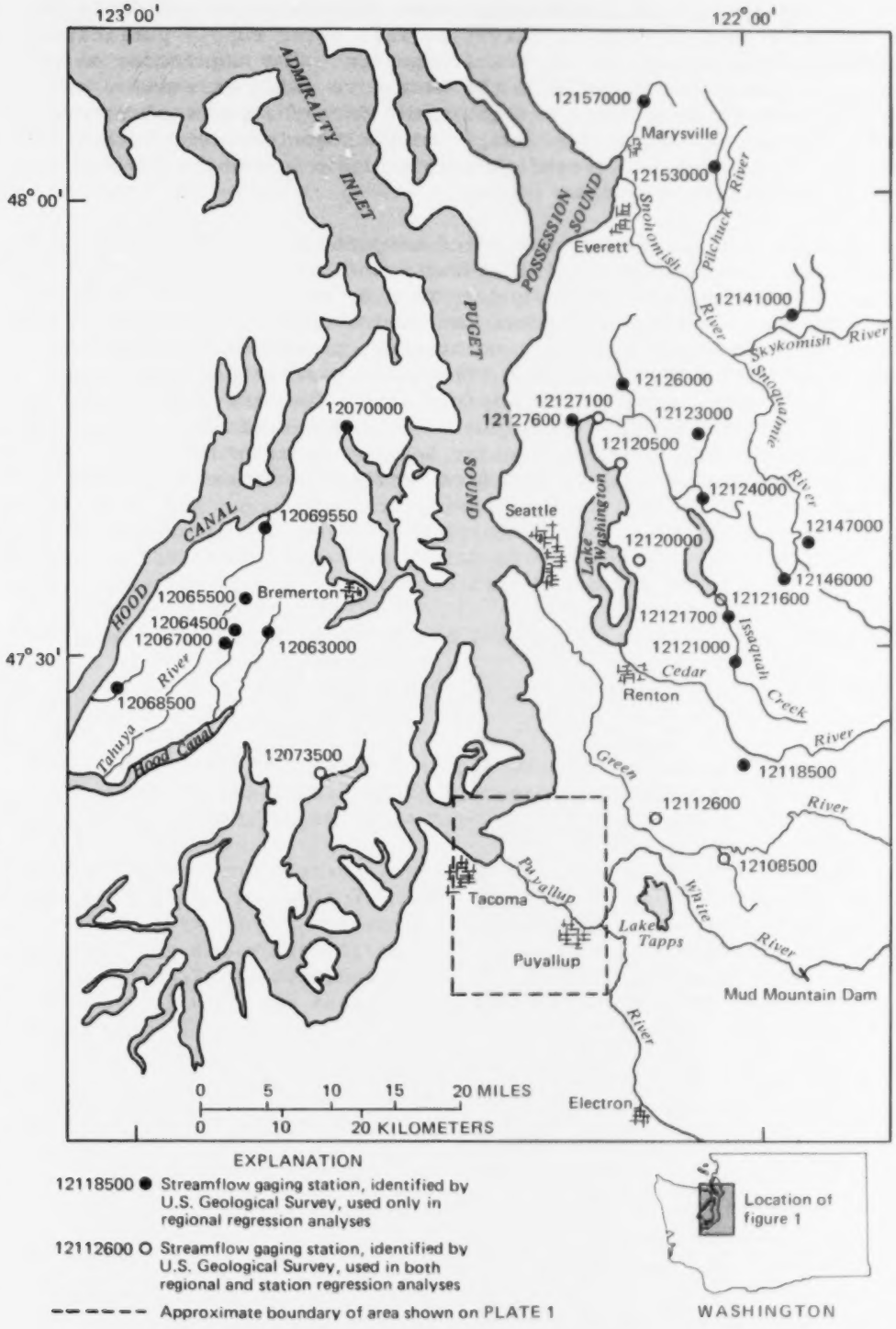

Figure 1.--Locations of streamflow gaging stations used in station and regional regression analyses.

Many of the gaging-station records under consideration are described in various United States Geological Survey surface-water supply publications as being affected by some diversions for irrigation. The magnitudes of these diversions are often not known, but the degree to which streamflow at these gages is affected by diversions was estimated from the plots of streamflow statistics against drainage area. Gages with diversions were included in the regression analyses unless streamflow statistics computed for them appeared to be significant outliers on these plots.

The accuracy of streamflow statistics computed from gaging-station data, especially those statistics for infrequent events, increase with the length of record from which they are determined. The U.S. Water Resources Council (1981, p. 2) recommends a standard procedure and a minimum of 10 years of record for flood-frequency analysis. However, no standard procedures or criteria for length of record exist for the other streamflow statistics included in this report. In this investigation the minimum allowable length of record was established by comparing the confidence band widths estimated for mean 7-day high and low flows with their respective lengths of records. This analysis indicated that only those gages with 8 or more years of record should be used.

Station Regression Analyses

Station regression equations were developed by regressing discharges from measurements made once, and occasionally twice, a month at each site with respect to concurrent daily mean discharges at selected long-term gaging stations. Measured discharges obtained during June 1983 through May 1984 at the small-stream sites and concurrent daily mean discharges at the selected gaging stations are given in tables 5 and 6, respectively.

The long-term gaging station used in the station regression analysis for a small-stream site was chosen from the 7 gaging stations among the 26 selected for use in the development of regression equations that were active at the time discharge measurements were made at the small-stream sites (see table 4 and figure 1). The choice was made by correlating the daily mean discharges at each of the seven long-term stations with the measured discharges at the small-stream site. Generally, the gaging station whose daily mean discharges correlated best with the measured discharges at a given small-stream site was selected for use in deriving the station regression equation for that site. However, in some instances a different gaging station was selected objectively, on the basis of the number and distribution of data points. Some gaging-station records contained fewer data points than others because of missing data. Two of the seven long-term gaging stations (12073500 and 12127100) were not used to develop any of the station regression equations.

The regression equations developed for the 16 small-stream sites each have the form:

$$Q = a + b(Q_g) \quad , \qquad (1)$$

where:

Q = discharge, in cubic feet per second, at small-stream site,
a and b = coefficients determined by regression analysis, and
Q_g = discharge, in cubic feet per second, at gaging station.

The station regression equation developed for each small-stream site on the reservation is given in table 7. Also included in table 7 are the coefficients of correlation between the measured discharges at each small-stream site and the corresponding daily mean discharges at the long-term gaging station used in the regression analysis for that site. These correlation coefficients range from 0.98 to 0.79 with the exception of one value of 0.58.

Table 5.--Measured discharges at small-stream sites on or near the Puyallup Indian Reservation

[Discharge, in cubic feet per second.
-- , no discharge measurement made.]

Date	Gaging-station number							
	12101478	12102020	12102050	12102075	12102100	12102110	12102115	12102175
1983								
June 14	--	0.41	1.14	--	62.7	0.00	0.00	14.1
June 15	0.18	--	--	--	--	--	--	--
July 14	.55	--	--	--	--	--	--	--
July 15	--	--	1.29	58.3	71.5	.00	.00	24.8
Aug. 9	--	--	.81	--	--	.00	--	13.2
Aug. 10	--	.28	--	54.0	56.2	--	--	--
Aug. 11	.18	--	--	--	--	--	--	--
Sept. 19	--	.18	.72	52.2	--	.00	.01	14.6
Sept. 20	.11	--	--	--	57.1	--	--	--
Oct. 17	.06	--	--	--	--	--	--	--
Oct. 18	--	.18	.59	53.9	61.5	.00	.01	16.3
Nov. 3	--	--	--	--	--	--	1.74	--
Nov. 17	--	.25	1.17	75.4	80.3	5.46	5.22	--
Nov. 18	.08	--	--	--	--	--	--	35.1
Dec. 14	--	.38	1.66	66.7	77.1	1.81	2.71	28.4
Dec. 15	.51	--	--	--	--	--	--	--
1984								
Jan. 23	.65	--	--	--	--	--	--	--
Jan. 24	--	.51	4.14	69.0	82.9	2.01	2.25	38.1
Feb. 20	--	--	--	--	--	--	--	--
Feb. 21	1.87	--	--	--	--	--	--	--
Feb. 22	--	.61	1.76	64.6	63.9	2.14	2.45	26.5
Mar. 19	.90	--	--	--	--	--	--	--
Mar. 20	--	.59	--	69.5	67.8	3.59	3.25	--
Mar. 21	--	--	2.01	--	--	6.06	6.27	44.7
Apr. 16	1.05	--	--	--	--	--	--	--
Apr. 17	--	.56	1.85	54.5	64.0	--	--	--
Apr. 18	--	--	--	--	--	.07	.01	22.3
May 15	.72	--	--	--	--	1.45	.66	21.7
May 16	--	.51	1.61	57.0	71.1	--	--	--

Table 5.--Continued

Date		Gaging-station number							
		12102202	12102212	12102490	12102510	12102900	12103000	12103025	12103035
1983									
June	14	0.00	2.59	--	--	--	--	--	--
June	15	--	--	0.19	2.87	1.22	5.73	10.7	0.47
July	14	--	--	.31	5.34	1.76	7.23	12.5	.88
July	15	.12	2.48	--	--	--	--	--	--
Aug.	9	.00	2.66	--	--	--	--	--	--
Aug.	10	--	--	--	--	--	--	--	--
Aug.	11	--	--	.00	1.75	1.11	5.01	8.35	.31
Sept.	19	.37	2.31	--	--	--	--	--	--
Sept.	20	--	--	.12	3.09	1.17	5.65	9.42	.44
Oct.	17	--	--	.08	2.73	1.47	7.02	11.8	1.56
Oct.	18	.00	2.08	--	--	--	--	--	--
Nov.	3	21.3	24.6	1.37	--	--	47.2	--	--
Nov.	17	19.6	24.6	--	--	--	--	--	--
Nov.	18	--	--	1.32	16.1	6.55	11.0	42.4	[a]15.9
Dec.	14	8.55	13.6	--	--	--	--	--	--
Dec.	15	--	--	1.27	14.1	8.09	10.2	33.7	4.20
1984									
Jan.	23	--	--	.70	6.73	3.07	8.23	41.4	2.55
Jan.	24	12.2	14.5	--	--	--	--	--	--
Feb.	20	--	--	--	--	--	--	21.4	12.4
Feb.	21	--	--	2.25	14.2	21.1	25.8	--	11.6
Feb.	22	7.12	11.7	--	--	--	--	66.3	--
Mar.	19	--	--	.99	7.98	6.94	9.81	27.0	3.29
Mar.	20	15.3	--	--	--	--	--	--	--
Mar.	21	18.9	28.2	--	--	--	--	--	--
Apr.	16	--	--	1.25	6.89	4.14	8.06	20.0	1.44
Apr.	17	1.52	5.06	--	--	--	--	--	--
Apr.	18	--	--	--	--	--	--	--	--
May	15	--	--	.75	6.99	7.74	12.1	29.2	4.71
May	16	2.98	6.50	--	--	--	--	--	--

[a]This measurement, which was made during a period of rapidly changing flow at the long-term gaging stations and was considered to be unrepresentative of the rapid flow changes at the gages based on comparison of flows during other similar periods, was not used in station regression analyses.

Table 6.--Daily mean discharges at long-term gaging stations used in station regression analyses

[Discharge, in cubic feet per second.
-- , no daily mean discharge available]

Date	Gaging-station number						
	12073500	12108500	12112600	12120000	12120500	12121600	12127100
1983							
June 14	6.7	24	48	10	--	43	--
June 15	6.7	26	48	9.9	--	43	--
July 14	6.5	82	83	--	17	150	--
July 15	6.1	51	63	24	17	160	18
Aug. 9	5.0	22	--	8.7	--	34	7.5
Aug. 10	5.1	21	--	9.0	--	34	8.0
Aug. 11	5.5	29	--	37	26	65	29
Sept. 19	6.1	31	53	16	11	69	20
Sept. 20	5.7	25	44	12	7.7	54	11
Oct. 17	5.9	20	37	17	5.9	43	9.1
Oct. 18	5.7	19	35	10	4.2	42	8.3
Nov. 3	21	351	138	163	70	392	106
Nov. 17	--	108	236	86	45	522	--
Nov. 18	--	98	219	41	22	355	--
Dec. 14	34	124	275	34	25	365	--
Dec. 15	24	112	255	27	14	300	--
1984							
Jan. 23	11	102	223	23	--	138	--
Jan. 24	--	399	318	64	--	742	--
Feb. 20	--	142	208	70	31	182	76
Feb. 21	--	207	298	44	27	266	95
Feb. 22	--	110	285	37	25	246	131
Mar. 19	21	--	168	28	15	153	45
Mar. 20	27	--	230	83	41	246	95
Mar. 21	31	--	332	59	25	400	109
Apr. 16	14	--	180	17	8.4	171	--
Apr. 17	12	--	170	15	7.7	156	--
Apr. 18	12	--	164	17	8.8	148	--
May 15	--	125	182	15	9.9	142	--
May 16	--	96	165	14	8.4	141	--

Table 7.--Station regression equations for estimation of streamflow statistics at small-stream sites on or near the Puyallup Indian Reservation

[Equations noted with the symbol '*' were graphically adjusted at their lower ends to improve the accuracy of estimated statistics with low discharges]

Station number	Small-stream site	Coefficient of correlation	Station regression equation
12101478	Wapato Creek diversion to Puyallup River at North Puyallup	0.89	$Q = -0.18 + 0.00816(Q_1)$
12102020	Diru Creek at inflow to hatchery near Puyallup	.58	$*Q = 0.25 + 0.000926(Q_2)$
12102050	Clarks Creek tributary at Pioneer Way near Puyallup	.98	$*Q = 0.63 + 0.00874(Q_1)$
12102075	Clarks Creek at Tacoma Road at Reservation Boundary	.96	$Q = 51 + 0.523(Q_4)$
12102100	Clarks Creek at River Road near Puyallup	.89	$*Q = 60 + 0.0355(Q_5)$
12102110	W.F. Clear Creek at 72nd St. E., Tacoma	.85	$Q = -0.57 + 0.0646(Q_3)$
12102115	E.F. Clear Creek at 72nd St. E., Tacoma	.79	$Q = -0.90 + 0.0154(Q_2)$
12102175	Clear Creek at 31st Ave. Court E., Tacoma	.95	$*Q = 11 + 0.505(Q_3)$
12102202	Swan Creek at Flume Line Road, Tacoma	.89	$*Q = 0.24 + 0.168(Q_3)$
12102212	Swan Creek at Pioneer Way, Tacoma	.81	$*Q = 3.5 + 0.177(Q_3)$
12102490	Wapato Creek at Union Pacific RR near North Puyallup	.87	$Q = -0.13 + 0.00648(Q_2)$
12102510	Wapato Creek at 12th St. E., Fife	.98	$Q = 0.12 + 0.0465(Q_5)$
12102900	Hylebos Creek above tributary at 5th Ave., Milton	.92	$Q = -2.6 + 0.0955(Q_1))$
12103000	West tributary to Hylebos Creek near Milton	.97	$Q = -0.09 + 0.124(Q_1)$
12103025	Hylebos Creek at 8th Ave. E., Fife	.86	$Q = 0.08 + 0.168(Q_2)$
12103035	Fife Ditch at 54th St. E., Fife	.87	$Q = -1.6 + 0.063(Q_1)$

where: Q = estimated streamflow statistic, in cubic feet per second, and

Q_1 - Q_5 = streamflow statistics at stream-gaging station numbers 12108500, 12112600, 12120000, 12120500, and 12121600, respectively.

Estimated Streamflow Statistics

Streamflow statistics for a small-stream site were estimated by entering streamflow statistics for the selected long-term gage into the station regression equation for the site. However, because examinations of graphs of discharge data and regression lines indicated that the statistics with low discharges would be significantly overestimated for six of the small-stream sites (12102020, 12102050, 12102100, 12102175, 12102202, and 12102212), the lower ends of these relations were adjusted graphically to improve the accuracy of the estimated statistics. The streamflow statistics for the five long-term gaging stations used in the station regressions are given in tables 8 through 11, and the statistics estimated for the small-stream sites are given in tables 12 through 15. The coefficient, a, in some of the equations is negative, which produces negative discharges for some streamflow statistics; these discharges were estimated to be zero.

Table 8.--Lowest mean daily discharges for periods of 7, 14, and 30 consecutive days with average recurrence intervals of 2 and 10 years at long-term gaging stations used in station regressions

	Discharge, in cubic feet per second					
Station number	7-day, 2-year	7-day, 10-year	14-day, 2-year	14-day, 10-year	30-day, 2-year	30-day, 10-year
12108500	16	13	17	13	18	14
12112600	30	26	31	26	33	27
12120000	5.2	3.7	5.6	4.0	6.1	4.3
12120500	2.7	2.2	2.8	2.3	3.0	2.4
12121600	27	21	28	21	30	23

Table 9.--Highest mean daily discharges for periods of 1, 3, 7, 15, and 30 consecutive days with average recurrence intervals of 2 and 10 years at long-term gaging stations used in station regressions

	Discharge, in cubic feet per second									
Station number	1-day, 2-year	1-day 10-year	3-day, 2-year	3-day, 10-year	7-day, 2-year	7-day, 10-year	15-day, 2-year	15-day 10-year	30-day 2-year	30-day 10-year
12108500	454	766	360	568	274	408	207	296	163	232
12112600	696	948	645	839	559	707	461	570	384	456
12120000	168	229	126	183	92	135	70	100	58	77
12120500	78	125	59	91	44	65	36	49	28	42
12121600	1,138	1,828	933	1,411	720	985	553	677	438	523

Table 10.--Mean monthly and annual discharges at long-term gaging stations used in station regressions

Station number	Discharge, in cubic feet per second												
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
12108500	27	63	105	124	107	91	71	48	39	26	21	22	62
12112600	45	90	235	276	249	215	148	91	66	44	36	39	127
12120000	14	28	42	43	36	31	22	14	11	7.8	8.1	11	22
12120500	5.6	12	22	22	16	16	11	6.8	5.5	3.9	3.8	4.6	11
12121600	58	140	286	315	240	208	157	95	78	47	37	46	142

Table 11.--Daily mean discharges equaled or exceeded 10, 25, 50, 75, and 90 percent of the time at long-term gaging stations used in station regressions

Station number	Discharge, in cubic feet per second				
	10 pct	25 pct	50 pct	75 pct	90 pct
12108500	120	76	43	24	18
12112600	292	177	78	42	34
12120000	48	27	15	8.6	6.2
12120500	23	13	7.0	4.1	3.1
12121600	310	180	91	46	31

Table 12.--Lowest mean daily discharges for periods of 7, 14, and 30 consecutive days with average recurrence intervals of 2 and 10 years that were estimated by station regression technique at small-stream sites on or near the Puyallup Indian Reservation

[Upper and lower limits are bounds on the 95-percent confidence bands for the estimated discharges. Statistics estimated using graphically adjusted regression relations are identified by the symbol '*'. No upper and lower bands were determined for these values.]

Small-stream site	Discharge, in cubic feet per second					
	7-day, 2-year	7-day, 10-year	14-day, 2-year	14-day, 10-year	30-day, 2-year	30-day 10-year
Wapato Creek diversion to Puyallup River at North Puyallup (12101478)						
Upper limit	0.6	0.6	0.6	0.6	0.6	0.6
Estimate	.0	.0	.0	.0	.0	.0
Lower limit	.0	.0	.0	.0	.0	.0
Diru Creek at inflow to hatchery near Puyallup (12102020)						
Estimate	.2*	.1*	.2*	.1*	.2*	.1*
Clarks Creek tributary at Pioneer Way near Puyallup (12102050)						
Estimate	.6*	.5*	.6*	.5*	.6*	.5*
Clarks Creek at Tacoma Road at Reservation Boundary (12102075)						
Upper limit	58	58	58	58	58	58
Estimate	52	52	52	52	53	52
Lower limit	47	47	47	47	47	47
Clarks Creek at River Road near Puyallup (12102100)						
Estimate	56*	55*	56*	55*	56*	55*
W.F. Clear Creek at 72nd St. E., Tacoma (12102110)						
Upper limit	2.5	2.5	2.5	2.5	2.5	2.5
Estimate	.0	.0	.0	.0	.0	.0
Lower limit	.0	.0	.0	.0	.0	.0
E.F. Clear Creek at 72nd St. E., Tacoma (12102115)						
Upper limit	3.0	3.0	3.0	3.0	3.0	3.0
Estimate	.0	.0	.0	.0	.0	.0
Lower limit	.0	.0	.0	.0	.0	.0
Clear Creek at 31st Ave. Ct. E., Tacoma (12102175)						
Estimate	12*	11*	12*	11*	13*	11*
Swan Creek at Flume Line Road, Tacoma (12102202)						
Estimate	.0*	.0*	.0*	.0*	.0*	.0*
Swan Creek at Pioneer Way, Tacoma (12102212)						
Estimate	1.9*	1.4*	2.0*	1.5*	2.2*	1.6*

Table 12.--Continued

Small-stream site	Discharge, in cubic feet per second					
	7-day, 2-year	7-day, 10-year	14-day, 2-year	14-day, 10-year	30-day, 2-year	30-day 10-year
Wapato Creek at Union Pacific RR near North Puyallup (12102490)						
Upper limit	0.8	0.8	0.8	0.8	0.8	0.8
Estimate	.1	.0	.1	.0	.1	.0
Lower limit	.0	.0	.0	.0	.0	.0
Wapato Creek at 12th St. E., Fife (12102510)						
Upper limit	3.8	3.5	3.8	3.5	3.9	3.6
Estimate	1.4	1.1	1.4	1.1	1.5	1.2
Lower limit	.0	.0	.0	.0	.0	.0
Hylebos Creek above tributary at 5th Ave., Milton (12102900)						
Upper limit	5.9	5.9	5.9	5.9	5.9	5.9
Estimate	.0	.0	.0	.0	.0	.0
Lower limit	.0	.0	.0	.0	.0	.0
West tributary to Hylebos Creek near Milton (12103000)						
Upper limit	9.3	8.9	9.3	9.0	9.4	9.0
Estimate	1.9	1.5	2.0	1.6	2.1	1.7
Lower limit	.0	.0	.0	.0	.0	.0
Hylebos Creek at 8th Ave. E., Fife (12103025)						
Upper limit	26	25	26	25	26	25
Estimate	5.2	4.4	5.3	4.5	5.5	4.7
Lower limit	.0	.0	.0	.0	.0	.0
Fife Ditch at 54th St. E., Fife (12103035)						
Upper limit	5.3	5.4	5.3	5.4	5.3	5.4
Estimate	.0	.0	.0	.0	.0	.0
Lower limit	.0	.0	.0	.0	.0	.0

Table 13.--Highest mean daily discharges for periods of 1, 3, 7, 15, and 30 consecutive days with average recurrence intervals of 2 and 10 years that were estimated by station regression technique at small-stream sites on or near the Puyallup Indian Reservation

[Upper and lower limits are bounds on the 95-percent confidence bands for the estimated discharges.]

Small-stream site	Discharge, in cubic feet per second									
	1-day, 2-year	1-day, 10-year	3-day, 2-year	3-day, 10-year	7-day, 2-year	7-day, 10-year	15-day, 2-year	15-day, 10-year	30-day, 2-year	30-day, 10-year
Wapato Creek diversion to Puyallup River at North Puyallup (12101478)										
Upper limit	4.8	8.5	3.6	6.1	2.9	4.3	2.2	3.1	1.8	2.4
Estimate	3.5	6.1	2.6	4.5	2.1	3.1	1.5	2.2	1.1	1.7
Lower limit	2.2	3.7	1.7	2.8	1.2	2.0	.8	1.4	.5	1.0
Diru Creek at inflow to hatchery near Puyallup (12102020)										
Upper limit	1.5	1.9	1.4	1.7	1.2	1.5	1.1	1.2	1.0	1.1
Estimate	.9	1.1	.8	1.0	.8	.9	.7	.8	.6	.7
Lower limit	.3	.3	.3	.3	.3	.3	.3	.3	.2	.3
Clarks Creek tributary at Pioneer Way near Puyallup (12102050)										
Upper limit	5.5	9.0	4.5	6.7	3.6	5.0	3.0	3.9	2.6	3.2
Estimate	4.6	7.3	3.8	5.6	3.0	4.2	2.4	3.2	2.1	2.7
Lower limit	3.7	5.7	3.1	4.5	2.4	3.4	1.9	2.6	1.5	2.1
Clarks Creek at Tacoma Road at Reservation Boundary (12102075)										
Upper limit	103	140	90	115	81	96	76	84	71	81
Estimate	92	116	82	99	74	85	70	76	66	73
Lower limit	81	93	74	82	67	75	64	69	60	65
Clarks Creek at River Road near Puyallup (12102100)										
Upper limit	117	151	107	130	97	108	89	95	85	88
Estimate	100	125	93	110	86	94	80	84	76	79
Lower limit	84	99	79	90	74	81	70	73	66	69
W.F. Clear Creek at 72nd St. E., Tacoma (12102110)										
Upper limit	14	20	11	16	8.2	12	6.5	8.9	5.7	7.0
Estimate	10	14	7.6	11	5.4	8.2	4.0	5.9	3.2	4.4
Lower limit	6.2	8.6	4.2	6.6	2.6	4.5	1.4	2.9	.7	1.7
E.F. Clear Creek at 72nd St. E., Tacoma (12102115)										
Upper limit	15	21	14	18	12	15	9.8	12	8.2	9.7
Estimate	9.8	14	9.0	12	7.7	10	6.2	7.9	5.0	6.1
Lower limit	4.8	6.9	4.4	6.0	3.6	4.9	2.6	3.7	1.8	2.6
Clear Creek at 31st Ave. Ct. E., Tacoma (12102175)										
Upper limit	113	155	89	127	69	97	55	74	49	59
Estimate	96	127	75	103	58	79	46	61	40	50
Lower limit	78	98	60	80	47	62	37	48	32	40

Table 13.--Continued

Small-stream site	Discharge, in cubic feet per second									
	1-day, 2-year	1-day, 10-year	3-day, 2-year	3-day, 10-year	7-day, 2-year	7-day, 10-year	15-day, 2-year	15-day, 10-year	30-day, 2-year	30-day, 10-year
Swan Creek at Flume Line Road, Tacoma (12102202)										
Upper limit	39	52	31	43	24	33	20	26	18	22
Estimate	28	39	21	31	16	23	12	17	10	13
Lower limit	18	25	12	19	7.1	13	3.7	8.0	1.8	4.7
Swan Creek at Pioneer Way, Tacoma (12102212)										
Upper limit	49	64	40	53	33	42	28	34	25	30
Estimate	33	44	26	36	20	27	16	21	14	17
Lower limit	17	24	12	18	6.8	13	3.3	7.7	1.4	4.4
Wapato Creek at Union Pacific RR near North Puyallup (12102490)										
Upper limit	6.0	8.3	5.6	7.3	4.8	6.1	3.9	4.9	3.3	3.9
Estimate	4.4	6.0	4.1	5.3	3.5	4.5	2.9	3.6	2.4	2.8
Lower limit	2.7	3.7	2.5	3.3	2.2	2.8	1.8	2.2	1.4	1.7
Wapato Creek at 12th St. E., Fife (12102510)										
Upper limit	66	108	53	82	40	54	30	37	24	29
Estimate	53	85	43	66	34	45	26	32	20	24
Lower limit	40	62	34	49	27	36	21	26	17	20
Hylebos Creek above tributary at 5th Ave., Milton (12102900)										
Upper limit	54	96	43	69	32	49	24	35	19	27
Estimate	41	71	32	52	24	36	17	26	13	20
Lower limit	27	45	21	34	15	24	10	17	6.7	12
West tributary to Hylebos Creek near Milton (12103000)										
Upper limit	69	120	55	87	43	62	34	46	28	37
Estimate	56	95	45	70	34	50	26	37	20	29
Lower limit	43	70	34	54	25	39	18	27	13	20
Hylebos Creek at 8th Ave. E., Fife (12103025)										
Upper limit	160	220	148	194	128	163	106	130	89	105
Estimate	117	159	108	141	94	119	78	96	65	77
Lower limit	74	98	69	88	60	75	49	61	40	48
Fife Ditch at 54th St. E., Fife (12103035)										
Upper limit	38	67	30	49	23	34	18	25	14	20
Estimate	27	47	21	34	16	24	11	17	8.6	13
Lower limit	16	26	12	20	8.4	14	5.4	9.3	3.2	6.5

Table 14.--Mean monthly and annual discharges that were estimated by station regression technique at small-stream sites on or near the Puyallup Indian Reservation

[Upper and lower limits are bounds on the 95-percent confidence bands for the estimated discharges. Statistics estimated using graphically adjusted regression relations are identified by the symbol '*'. No upper and lower bands were determined for these values.]

Small-stream site	Discharge, in cubic feet per second												
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
Wapato Creek diversion to Puyallup River at North Puyallup (12101478)													
Upper limit	0.6	0.9	1.2	1.4	1.3	1.1	0.9	0.8	0.7	0.6	0.6	0.6	0.9
Estimate	.0	.3	.7	.8	.7	.6	.4	.2	.1	.0	.0	.0	.3
Lower limit	.0	.0	.1	.3	.1	.0	.0	.0	.0	.0	.0	.0	.0
Diru Creek at inflow to hatchery near Puyallup (12102020)													
Upper limit		.6	.8	.8	.8	.8	.7	.6					.7
Estimate	.2*	.3	.5	.5	.5	.4	.4	.3	.2*	.2*	.2*	.2*	.4
Lower limit		.0	.2	.2	.2	.1	.1	.0					.1
Clarks Creek tributary at Pioneer Way near Puyallup (12102050)													
Upper limit		1.7	2.1	2.2	2.1	1.9	1.7						
Estimate	.7*	1.2	1.5	1.7	1.6	1.4	1.2	1.0*	.9*	.7*	.6*	.6*	1.1*
Lower limit		.7	1.0	1.2	1.1	.9	.8						
Clarks Creek at Tacoma Road at Reservation Boundary (12102075)													
Upper limit	59	63	68	68	65	65	62	60	59	59	59	59	62
Estimate	54	57	62	63	60	59	57	55	54	53	53	53	57
Lower limit	48	52	57	57	54	54	52	49	48	47	47	48	51
Clarks Creek at River Road near Puyallup (12102100)													
Upper limit			79	80	77	76							74
Estimate	59*	64*	70	71	69	67	65*	62*	60*	58*	57*	58*	65
Lower limit	53	56	61	62	60	58							56
W.F. Clear Creek at 72nd St. E., Tacoma (12102110)													
Upper limit	2.8	3.6	4.6	4.6	4.2	3.9	3.3	2.8	2.6	2.5	2.5	2.6	3.3
Estimate	.4	1.2	2.2	2.2	1.8	1.5	.8	.3	.2	.0	.0	.1	.9
Lower limit	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
E.F. Clear Creek at 72nd St. E., Tacoma (12102115)													
Upper limit	3.0	3.4	5.7	6.3	5.8	5.3	4.2	3.4	3.0	3.0	3.0	3.0	3.9
Estimate	.0	.5	2.7	3.4	2.9	2.4	1.4	.5	.1	.0	.0	.0	1.1
Lower limit	.0	.0	.0	.4	.0	.0	.0	.0	.0	.0	.0	.0	.0
Clear Cr at 31st Ave. Ct. E., Tacoma (12102175)													
Upper limit	26	32	40	40	37	34	29	25				24	29
Estimate	18	25	32	32	29	27	22	18	16*	14*	14*	18	22
Lower limit	11	18	25	25	22	19	15	11				9.1	15

Table 14.--Continued

Small-stream site	Discharge, in cubic feet per second												
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
Swan Creek at Flume Line Road, Tacoma (12102202)													
Upper limit		13	16	16	15	14							
Estimate	1.7*	4.9	7.3	7.4	6.3	5.5	3.7*	1.7*	0.8*	0.0*	0.0*	0.8*	3.7*
Lower limit		.0	.0	.0	.0	.0							
Swan Creek at Pioneer Way, Tacoma (12102212)													
Upper limit			23	23	22	21							
Estimate	4.8*	8.3*	11	11	9.9	9.0	6.9*	4.8*	3.8*	2.8*	2.9*	3.8*	6.9*
Lower limit			.0	.0	.0	.0							
Wapato Creek at Union Pacific RR near North Puyallup (12102490)													
Upper limit	.9	1.2	2.2	2.5	2.3	2.0	1.6	1.2	1.0	.9	.9	.9	1.4
Estimate	.2	.4	1.4	1.7	1.5	1.3	.8	.5	.3	.2	.1	.1	.7
Lower limit	.0	.0	.6	.8	.7	.5	.1	.0	.0	.0	.0	.0	.0
Wapato Creek at 12th St. E., Fife (12102510)													
Upper limit	5.2	9.4	17	18	14	13	9.8	6.8	6.2	4.7	4.2	4.6	9.1
Estimate	2.8	6.6	13	15	11	9.8	7.4	4.5	3.8	2.3	1.8	2.2	6.7
Lower limit	.4	3.9	10	11	8.2	6.9	5.0	2.2	1.3	.0	.0	.0	4.4
Hylebos Creek above tributary at 5th Ave., Milton (12102900)													
Upper limit	5.8	9.1	13	15	13	12	9.7	7.7	6.8	5.8	5.8	5.8	8.9
Estimate	.0	3.4	7.4	9.2	7.6	6.1	4.2	2.0	1.1	.0	.0	.0	3.3
Lower limit	.0	.0	1.6	3.3	1.9	.4	.0	.0	.0	.0	.0	.0	.0
West tributary to Hylebos Creek near Milton (12103000)													
Upper limit	11	15	20	23	20	18	16	13	12	10	9.8	10	15
Estimate	3.2	7.7	13	15	13	11	8.7	5.9	4.7	3.2	2.5	2.6	7.6
Lower limit	.0	.4	5.6	7.9	5.9	3.9	1.5	.0	.0	.0	.0	.0	.4
Hylebos Creek at 8th Ave. E., Fife (12103025)													
Upper limit	28	35	61	68	63	57	44	35	31	28	26	27	40
Estimate	7.6	15	40	46	42	36	25	15	11	7.4	6.1	6.7	21
Lower limit	.0	.0	18	25	21	16	5.9	.0	.0	.0	.0	.0	2.4
Fife Ditch at 54th St. E., Fife (12103035)													
Upper limit	5.3	7.5	10	11	10	9.2	7.9	6.6	6.0	5.3	5.3	5.3	7.4
Estimate	.1	2.4	5.0	6.2	5.1	4.1	2.9	1.4	.8	.1	.0	.0	2.3
Lower limit	.0	.0	.0	1.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Table 15.--Daily mean discharges equaled or exceeded 10, 25, 50, 75, and 90 prcent of the time that were estimated by station regression technique at small-stream sites on or near the Puyallup Indian Reservation

[Upper and lower limits are bounds on the 95-percent confidence bands for the estimated discharges. Statistics estimated using graphically adjusted regression relations are identified by the symbol '*'. No upper and lower bands were determined for these values.]

Small-stream site	Discharge, in cubic feet per second				
	10 pct	25 pct	50 pct	75 pct	90 pct
Wapato Creek diversion to Puyallup River at North Puyallup (12101478)					
Upper limit	1.4	1.0	0.7	0.6	0.6
Estimate	.8	.4	.2	.0	.0
Lower limit	.2	.0	.0	.0	.0
Diru Creek at inflow to hatchery near Puyallup (12102020)					
Upper limit	.8	.7	.6		
Estimate	.5	.4	.3	.2*	.2*
Lower limit	.2	.1	.0		
Clarks Creek tributary at Pioneer Way near Puyallup (12102050)					
Upper limit	2.2	1.8			
Estimate	1.7	1.3	.9*	.7*	.6*
Lower limit	1.2	.8			
Clarks Creek at Tacoma Road at Reservation Boundary (12102075)					
Upper limit	69	63	60	59	58
Estimate	63	58	55	53	53
Lower limit	57	52	49	48	47
Clarks Creek at River Road near Puyallup (12102100)					
Upper limit	80	75			
Estimate	71	66	61*	58*	56*
Lower limit	62	57			
W.F. Clear Creek at 72nd St. E., Tacoma (12102110)					
Upper limit	5.0	3.6	2.8	2.5	2.5
Estimate	2.5	1.2	.4	.0	.0
Lower limit	.1	.0	.0	.0	.0
E.F. Clear Creek at 72nd St. E., Tacoma (12102115)					
Upper limit	6.6	4.7	3.2	3.0	3.0
Estimate	3.6	1.8	.3	.0	.0
Lower limit	.6	.0	.0	.0	.0
Clear Creek at 31st Ave. Ct. E., Tacoma (12102175)					
Upper limit	43	32			
Estimate	35	25	18*	14*	13*
Lower limit	27	17			

Table 15.--Continued

Small-stream site	Discharge, in cubic feet per second				
	10 pct	25 pct	50 pct	75 pct	90 pct
Swan Creek at Flume Line Road, Tacoma (12102202)					
Upper limit	17	13			
Estimate	8.3	4.8	1.9*	0.0*	0.0*
Lower limit	.1	.0			
Swan Creek at Pioneer Way, Tacoma (12102212)					
Upper limit	24				
Estimate	12	8.0*	5.1*	3.0*	2.2*
Lower limit	.0				
Wapato Creek at Union Pacific RR near North Puyallup (12102490)					
Upper limit	2.6	1.8	1.1	.9	.9
Estimate	1.8	1.0	.4	.1	.1
Lower limit	.9	.3	.0	.0	.0
Wapato Creek at 12th St. E., Fife (12102510)					
Upper limit	18	11	6.7	4.6	3.9
Estimate	15	8.5	4.4	2.3	1.6
Lower limit	11	5.9	2.0	.0	.0
Hylebos Creek above tributary at 5th Ave., Milton (12102900)					
Upper limit	15	10	7.2	5.8	5.9
Estimate	8.9	4.7	1.5	.0	.0
Lower limit	3.0	.0	.0	.0	.0
West tributary to Hylebos Creek near Milton (12103000)					
Upper limit	22	17	12	10	9.5
Estimate	15	9.3	5.2	2.9	2.1
Lower limit	7.5	2.1	.0	.0	.0
Hylebos Creek at 8th Ave. E., Fife (12103025)					
Upper limit	72	49	33	27	26
Estimate	49	30	13	7.1	5.8
Lower limit	27	10	.0	.0	.0
Fife Ditch at 54th St. E., Fife (12103035)					
Upper limit	11	8.3	6.3	5.3	5.3
Estimate	6.0	3.2	1.1	.0	.0
Lower limit	.8	.0	.0	.0	.0

Confidence Bands of Estimates

The standard errors of prediction used to compute 95-percent confidence band limits for streamflow statistics estimated using station regression equations were obtained from the equation:

$$S_p = \sqrt{\sigma_R^2 + b^2 \sigma_T^2} \quad , \tag{2}$$

where:

S_p = standard error of prediction of streamflow statistic estimated for a small-stream site, in cubic feet per second,

σ_R = standard error of prediction of station regression equation used to estimate streamflow statistic, in cubic feet per second,

b = slope of station regression equation used to estimate streamflow statistic, and

σ_T = time-sampling standard error of streamflow statistic at long-term gaging station used in station regression equation, in cubic feet per second.

Standard errors of prediction of the station regression equations used to estimate streamflow statistics for the small-stream sites were computed with the following equation, which is similar to one obtained from Snedecor and Cochran (1967, p. 155, eq. 6.12.1):

$$\sigma_R = S_e \sqrt{1 + \frac{1}{N} + \left(\frac{\sum_{n=1}^{N} Q_n}{N} - Q_g \right)^2 \Bigg/ \sum_{n=1}^{N} \left(Q_n - \frac{\sum_{n=1}^{N} Q_n}{N} \right)^2} \quad , \tag{3}$$

where:

σ_R = standard error of prediction of station regression equation used to estimate streamflow statistic for a small-stream site, in cubic feet per second,

S_e = root mean square error of regression equation, in cubic feet per second,

N = number of discharge measurements made at small-stream site,

Q_n = daily mean discharge at long-term gaging station on the day that the nth discharge measurement was made at small-stream site, in cubic feet per second, and

Q_g = streamflow statistic at gaging station, in cubic feet per second.

The time-sampling standard errors (σ_T) for most of the streamflow statistics at the five long-term gaging stations were obtained using methods given by Hardison (1971). Hardison does not give a method for determining the time-sampling standard errors for flow-duration discharges. Consequently, time-sampling standard errors for these discharges were estimated from plots of the discharges estimated for the other streamflow statistics against the time-sampling standard errors.

The importance of the time-sampling standard errors in the determination of confidence band limits was evaluated in terms of the percentage differences between the standard errors of prediction used to determine the confidence band

limits and the standard errors of the station regression equations from which the streamflow statistics were estimated. These differences were less than 1 percent for all low-flow streamflow statistics, for most of the October, April through September, and annual-mean statistics, and for most of the 50-, 75-, and 90-percent flow-duration statistics. Percentage differences were less than 5 percent for approximately 80 percent of both the November through March monthly mean statistics and the 10- and 25-percent flow-duration statistics. Approximately 60 percent of the percentage differences for high-flow statistics were less than 10 percent, and only 15 percent were greater than 20 percent. The 95-percent confidence band limits for streamflow statistics estimated using station regression equations are given in tables 12 through 15.

Regional Regression Analyses

Regional regression equations were used to estimate peak discharges for the small-stream sites on the Puyallup Indian Reservation. These equations were obtained by regressing flood-frequency discharges for the 26 long-term gaging stations with respect to the drainage area and mean annual precipitation for each of the gages. The flood-frequency discharges for each of the gaging stations are given in table 16.

Table 16.--Annual peak discharges with average recurrence intervals of 10, 50, and 100 years at long-term gaging stations used in regional regression analyses

Station number	Discharge, in cubic feet per second		
	10-year	50-year	100-year
12063000	469	632	701
12064500	102	134	147
12065500	209	283	313
12067000	72	100	113
12068500	1,680	2,250	2,500
12069550	790	945	1,000
12070000	219	310	352
12073500	283	477	577
12108500	1,190	1,750	2,010
12112600	1,010	1,240	1,330
12118500	154	221	249
12120000	353	468	521
12120500	209	291	329
12121000	1,300	2,050	2,440
12121600	2,310	3,120	3,460
12121700	310	465	535
12123000	135	187	209
12124000	186	233	251
12126000	446	568	619
12127100	500	575	603
12127600	215	273	296
12141000	2,100	2,770	3,050
12146000	331	432	478
12147000	666	976	1,120
12153000	450	614	684
12157000	235	295	321

Drainage area and mean annual precipitation were selected for use as independent parameters in the development of regional regression equations based on the results of a step-forward linear-regression analysis. Other basin characteristics in WATSTORE included in the analysis were percentage of drainage area covered by forests; percentage of drainage area covered by lakes, ponds, and swamps; mean basin elevation; and main channel slope. The analysis determined a coefficient for each independent parameter and computed the probability that the value of that coefficient was not zero. Drainage area and mean annual precipitation were the only parameters used in the development of the regression equations because they were the only ones whose coefficients had a 95-percent or higher probability of having non-zero values. The drainage area and mean annual precipitation for each of the gaging stations used in the analysis are given in table 4.

The regression equations developed for estimating peak discharges at the small-stream sites all have the form:

$$Q = a(A)^{b}(P)^{c} \quad , \qquad (4)$$

where:

Q = peak discharge, in cubic feet per second, at small-stream site,
a,b, and c = coefficients determined by regression analysis,
A = contributing surface-drainage area, in square miles, at small-stream site, and
P = mean annual precipitation, in inches, at small-stream site.

The equations were developed using linear regression analyses of log-transformed data. This technique minimized percentage errors rather than absolute errors in fitting the regression lines to the data. The regional regression equation thus developed for each flood-frequency statistic is given in table 17.

Table 17.--Regional regression equations for estimation of annual peak discharges with average recurrence intervals of 10, 50, and 100 years at small-stream sites on or near the Puyallup Indian Reservation

Recurrence interval	Regional regression equation
10 years	$Q = 0.0173(A)^{0.769}(P)^{2.11}$
50 years	$Q = 0.0122(A)^{0.761}(P)^{2.28}$
100 years	$Q = 0.0108(A)^{0.759}(P)^{2.34}$

where:
Q = estimated annual peak discharge, in cubic feet per second,
A = contributing surface-drainage area, in square miles, and
P = mean annual precipitation, in inches.

Many basin characteristics that may affect streamflow, such as the amount of impervious area, were not included in the regression analyses because data were not available in WATSTORE. However, the omission of this parameter does not invalidate the use of the regression equations for the small reservation streams because the generally moderate degree of urbanization in the reservation drainage basins lies within the range of urbanization (little to moderate) for the basins at the long-term stations used in the regression analyses.

Estimated Peak Discharges

Annual peak discharges with average recurrence intervals of 10, 50, and 100 years were estimated for the small-stream sites by entering the independent parameter values of mean annual precipitation and drainage area determined for that site into the regional regression equations given in table 17. The estimated peak discharges are given in table 18. The mean annual precipitation used at each site was 38 inches, the average of the mean annual precipitation at Puyallup 2 West Experimental Station and at Tacoma City Hall, two long-term precipitation stations (U.S. Department of Commerce, 1981) located near the Puyallup Indian Reservation. The drainage areas for the small-stream sites (pl. 1) are given in table 1. Some of these were obtained from a report by Richardson (1962), others were determined from topographic maps (U.S. Department of the Interior).

Table 18.--Annual peak discharges with average recurrence intervals of 10, 50, and 100 years that were estimated by regional regression technique at small-stream sites on or near the Puyallup Indian Reservation

[Upper and lower limits are bounds on the 95-percent confidence bands for the estimated discharges.]

Small-stream site	Discharge, in cubic feet per second		
	10-year	50-year	100-year
Wapato Creek diversion to Puyallup River at North Puyallup (12101478)			
Upper limit	147	195	217
Estimate	50	66	72
Lower limit	17	22	24
Diru Creek at inflow to hatchery near Puyallup (12102020)			
Upper limit	125	165	184
Estimate	42	55	61
Lower limit	14	18	20
Clarks Creek tributary at Pioneer Way near Puyallup (12102050)			
Upper limit	153	202	225
Estimate	52	68	75
Lower limit	18	23	25
Clarks Creek at Tacoma Road at Reservation Boundary (12102075)			
Upper limit	746	969	1,070
Estimate	268	344	376
Lower limit	96	122	132
Clarks Creek at River Road near Puyallup (12102100)			
Upper limit	891	1,150	1,280
Estimate	319	408	447
Lower limit	114	144	156
W.F. Clear Creek at 72nd St. E., Tacoma (12102110)			
Upper limit	90	120	134
Estimate	30	39	43
Lower limit	9.7	13	14
E.F. Clear Creek at 72nd St. E., Tacoma (12102115)			
Upper limit	150	199	221
Estimate	51	67	74
Lower limit	18	23	25
Clear Creek at 31st Ave. Ct. E., Tacoma (12102175)			
Upper limit	539	702	780
Estimate	194	249	273
Lower limit	70	89	96

Table 18.--Continued

Small-stream site	Discharge, in cubic feet per second		
	10-year	50-year	100-year
Swan Creek at Flume Line Road, Tacoma (12102202) [a]			
Upper limit	211	294	331
Estimate	172	223	244
Lower limit	150	187	201
Swan Creek at Pioneer Way, Tacoma (12102212) [a]			
Upper limit	211	294	331
Estimate	172	223	244
Lower limit	150	187	201
Wapato Creek at Union Pacific RR near North Puyallup (12102490)			
Upper limit	80	106	119
Estimate	26	34	37
Lower limit	8.3	11	12
Wapato Creek at 12th St. E., Fife (12102510)			
Upper limit	274	359	400
Estimate	97	126	138
Lower limit	34	44	48
Hylebos Creek above tributary at 5th Ave., Milton (12102900)			
Upper limit	347	454	505
Estimate	124	160	176
Lower limit	44	56	61
West tributary to Hylebos Creek near Milton (12103000)			
Upper limit	480	626	696
Estimate	172	222	244
Lower limit	62	79	85
Hylebos Creek at 8th Ave. E., Fife (12103025)			
Upper limit	908	1,180	1,300
Estimate	325	415	455
Lower limit	116	147	159
Fife Ditch at 54th St. E., Fife (12103035)			
Upper limit	186	244	273
Estimate	64	84	92
Lower limit	22	29	31

[a] Discharges for sites 12102202 and 12102212 were estimated from flood-frequency analysis of the 21 annual peak discharges for crest-stage partial-record station 12102200.

Confidence Bands of Estimates

The standard errors of prediction used in the computation of 95-percent confidence band limits for streamflow statistics estimated using regional regression equations are given by the following modified form of an equation obtained from Snedecor and Cochran (1967, p. 392, eq. 13.5.5):

$$S_p = S_e \sqrt{1 + \frac{1}{N} + \frac{P^2 \sum_{n=1}^{N} A_n^2 + A^2 \sum_{n=1}^{N} P_n^2 - 2AP \sum_{n=1}^{N} A_n P_n}{\sum_{n=1}^{N} A_n^2 \cdot \sum_{n=1}^{N} P_n^2 - \left(\sum_{n=1}^{N} A_n \cdot P_n \right)^2}} \quad , \qquad (5)$$

where:

S_p = standard error of prediction of peak discharge estimated for a small-stream site,

S_e = root mean square error of regression equation,

N = number of gaging-station records used in regression analysis,

A_n = contributing surface-drainage area for the nth gaging-station record,

P_n = mean annual precipitation for the nth gaging-station record,

A = contributing surface-drainage area at the stream site for which peak discharge was estimated, and

P = mean annual precipitation at the stream site for which peak discharge was estimated.

This equation does not account for the time-sampling errors in the peak discharges at the long-term gaging stations.

Values of the independent parameters used in equation 5, as well as the standard errors of prediction computed from the equation, are in log-transformed units. Therefore, 95-percent confidence band limits for the estimated peak discharges were also computed in log units, which first required transforming the peak discharges to log units, and were then transformed to discharges, in cubic feet per second.

The upper and lower limits of the 95-percent confidence bands for the estimated peak discharges are given in table 18. These confidence bands typically extend from one-third to three times the estimated discharges. The 95-percent confidence band limits for the peak discharges estimated for the two Swan Creek sites, which were obtained from the flood-frequency analysis used to estimate those peak discharges, are also given in table 18.

SUMMARY AND CONCLUSIONS

Streamflow statistics were estimated for 16 sites on seven small streams and their tributaries near where they enter the Puyallup Indian Reservation and near their mouths. These streams are Clarks, Clear, Diru, Hylebos, Swan, and Wapato Creeks, and Fife Ditch. Streamflow statistics were computed for the Puyallup River from records for the stream-gaging station at Puyallup, located 0.8 mile downstream from the eastern reservation boundary. The statistics determined were 7-, 14-, and 30-day 2- and 10-year low flows; 1-, 3-, 7-, 15-, and 30-day 2- and 10-year high flows; mean monthly and annual flows; daily mean flows equaled or exceeded 10, 25, 50, 75, and 90 percent of the time; and 10-, 50-, and 100-year annual peak discharges.

For the small-stream sites, station regression relations were used to estimate all streamflow statistics except for peak discharges, which were estimated using regional regression equations. The upper and lower limits of the 95-percent confidence band were computed for each estimated statistic. The station regression equations were developed by regressing discharges measured about monthly for a year at the sites with respect to concurrent daily mean discharges at long-term gaging stations. The correlation coefficients between these discharges range from 0.98 to 0.79 with the exception of one value of 0.58. The lower ends of some of the regression relations were graphically adjusted to improve the accuracy with which low discharges would be estimated. Streamflow statistics at the long-term stations were entered into the station regression equations or transferred graphically for the adjusted regressions to obtain the corresponding streamflow statistics at the small-stream sites. The regional regression equations for peak discharges express each statistic as a function of contributing surface-drainage area and mean annual precipitation. These equations were developed using data for 26 gaging stations in the Puget Sound area. The 95-percent confidence bands for the estimated peak discharges typically extend from one-third to three times the estimated discharges.

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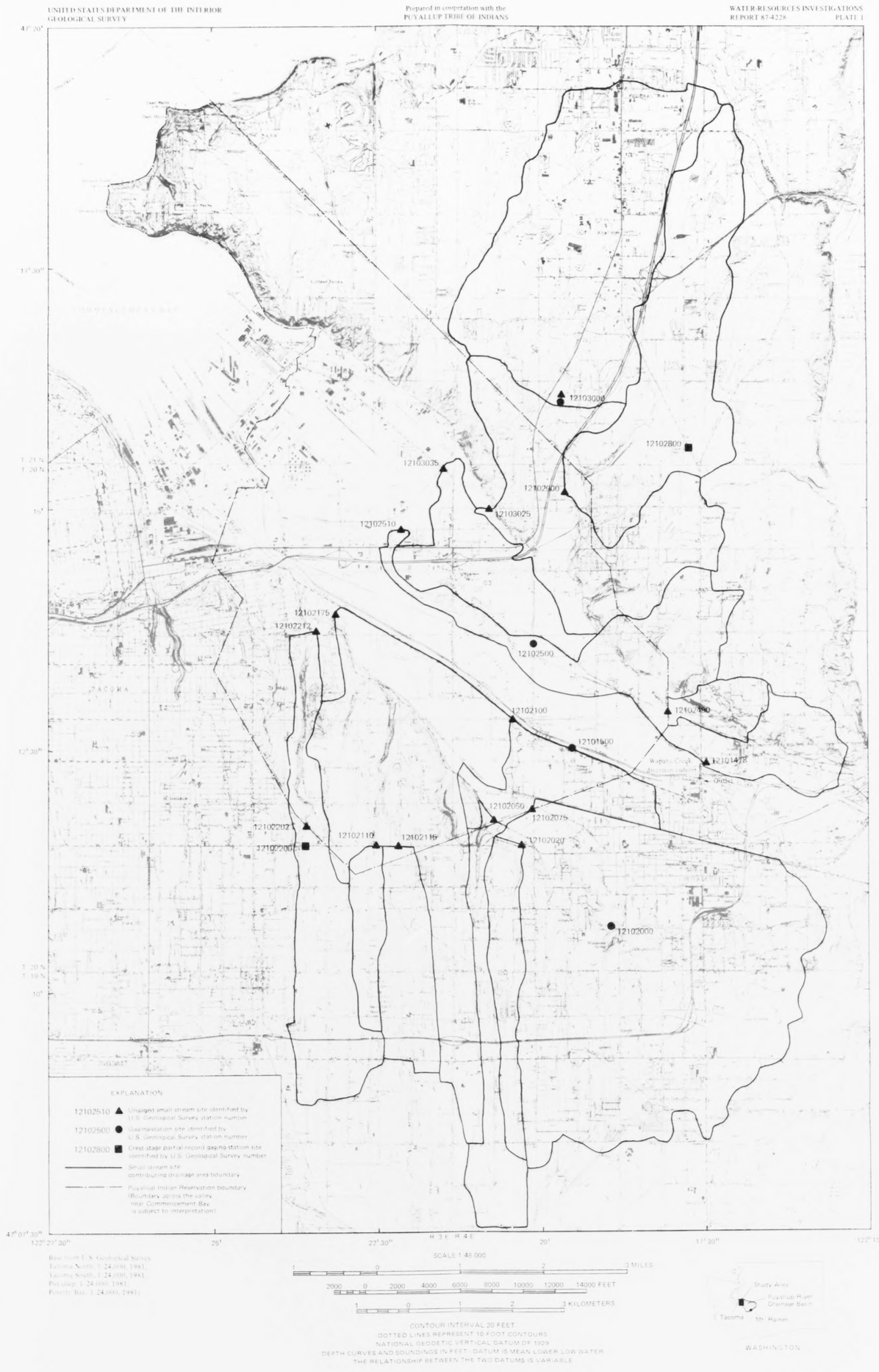

PLATE 1.--LOCATION OF STUDY AREA AND SITES FOR WHICH STREAMFLOW STATISTICS WERE COMPUTED

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